

IRRIGATION-ORIENTED ET MODELS FOR THE GREAT PLAINS¹Marvin E. Jensen and James L. Wright²

An evapotranspiration (ET) model is a mathematical expression relating the major climate, crop, and soil variables to ET. Modeling is a systematic and organized approach to solving a problem. It requires a look at the "whole picture" and not just the segments of interest. It also requires work on the entire system under natural environments and not segments of the system under artificial environments. Modeling enables researchers to develop more rigorous hypotheses before establishing experiments, thereby minimizing wasted effort and replotting old ground. The experience a researcher gains in developing a basic model for a segment of his work is invaluable since modeling requires establishing quantitative relationships, a consideration of all major variables, and long-range planning. Finally, contrary to popular opinions, models need not be extremely complex to be useful.

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An irrigation-oriented ET model is not new. Proponents of such a model have been active for over 20 years, but a general, suitable model was not developed and tested until recently. If one considers the millions of dollars spent on ET research during the past two decades, the limited amount of this technology used by the modern irrigation farm manager is appalling. Irrigation decisions (timing and amounts) are being made today in much the same manner as they were a quarter century ago. Part of this lag can be attributed to inadequate computing and communication facilities prior to 1960. As researchers and technologists, we have not demonstrated that we can make full use of current ET knowledge. Instead, we continue to seek the irrigationist's support for grandiose new studies. Irrigation-oriented ET models for the Great Plains can advance the application of modern technology, and their use has a tremendous pay-off potential.

This paper illustrates how such Great Plains ET models can be easily developed. It also includes a status report on the development and testing of a similar model that is being placed in use in arid areas and some areas of the Great Plains.

REQUIREMENTS OF IRRIGATION ET MODELS

The potential users and beneficiaries of a model must be defined before development begins. Development of a product without a market, or development in an unuseable form, is an extravagant venture. The

potential user must be involved at an early stage in the development of a user-oriented ET model to ascertain that it will meet his needs and abilities. Acceptable accuracy must be established early in the development of a first-generation model. If acceptable accuracy is not specified, researchers are reluctant to pause in the development of one component or phase and proceed on to the next. This does not mean that refinement should not be carried on, but rather that refinement can proceed without delaying the development and use of the model. Similarly, very accurate input data on the climate, crops, and soils are desirable, but why not proceed with existing or easily obtainable data? Then, as the use of a model expands, the input data can be refined simultaneously. Testing and verification are also essential in model development. Such testing and verification will require a few well-instrumented sites representing the range in climatic conditions encountered in the Great Plains.

MAJOR USERS OF IRRIGATION-ORIENTED ET MODELS

There are three general groups of potential users of irrigation-oriented ET models.

- A. Farm and project managers--principally through service companies or user-groups, canal companies, and basin authorities.

- B. Farm, project and basin planners, system designers and hydrologists.
- C. Researchers using a model as a tool to evaluate the effects of numerous combinations of variables and in planning field experiments.

Most of the potential users are in group A. They also are paying most of the research bill. Users in group B can and do use existing experimental data, but they need better models. Users in group C may, but not always, require more complex models. Such models usually become research tools.

CHARACTERISTIC OUTPUT FROM IRRIGATION-ORIENTED ET MODELS

The output information desired from irrigation-oriented ET models are distinctly different, depending on the use and purpose of the model. Three types of output information are:

- I. Decision-making data consisting of current daily ET values, not over 2 days old with cumulative resulting effects of previous 3- to 60-day periods. The output also includes forecasts of ET and ET effects. These data could be extremely valuable to the modern farm and project managers, but currently are almost nonexistent.

- II. Historical ET data are developed from climatic data collected in previous seasons and are the most common today. These are required mostly by groups B and C, and are used with rainfall-frequency distributions in project planning, investment analyses, evaluation of new practices, etc.
- III. Interaction data represent the combined effects of various climates, crops, and soils. These data require basic research input. Relationships between plant-water stress and daily plant growth are urgently needed in decision-making ET models, but such fundamental relationships are almost nonexistent, and simple, empirical functions are currently being used.

OPERATIONAL ASPECTS

The potential user of the data resulting from ET models must be alerted to the possible applications and potential benefits to be derived. He must begin adjusting his operations to capitalize on the use of these data. However, two-way communication is essential to optimize the format, frequency, and scope of information provided. Similarly, training of the technicians operating the model is important. Lack of experience is delaying the use of the recently developed USDA irrigation ET model.

The communication network between the basic data supplier, output data user, and the operator of the model is relatively crude and needs refinement. Two-way information exchange is involved, i.e., the decisions made by the farm manager and resulting management activities are essential inputs to irrigation-oriented models. Automatic telephone data transmission and data storage banks will become common, as will computers with audio-response capabilities for direct access by the user. Similarly, special-frequency radios such as those used for marine weather forecasting, or small, teletype units for receiving and sending data may be adopted. Feedback information and periodic monitoring of predicted soil moisture and dates of irrigation are extremely important. Satellites can provide some of this information in the future. Organized ground-observation networks are extremely flexible and have a large cost advantage today, but are virtually untapped.

An input climatic data network is also needed. The Great Plains is fortunate in having uniform climatic regimes that are not greatly influenced by orographic features found in mountainous regions. Good meteorological data, collected at selected key agricultural sites, can be representative of large areas. Satellite data (such as cloud cover) can be used immediately to extend ground measurements of solar or net radiation measurements at selected sites. Rainfall should be provided for individual farms or fields involved.

ACCURACY REQUIREMENTS

required for an ET model designed to be used for irrigation is not great. Estimates to 15% are adequate. If the error obtained over an irrigation interval error diminishes with $\sqrt{\text{days}}$ involved, estimates within $\pm 10\%$ for monthly estimates used on a daily basis. Predictions on ± 1 day is adequate for 10-day estimates usually adequate for 20-day estimates within $\pm 10\%$ are usually adequate for models.

required for ET models used in research for special purpose for which they are to be needed.

Accuracy limits are established that are indicated above, four to six well-insulated basins may be adequate for the Great Plains key stations could be obtained by physical models. Rainfall data should be involved. Testing and verification should be carried out near these key stations.

STATUS OF THE USDA IRRIGATION-ORIENTED ET MODEL

A decision-making, first-generation irrigation ET model has been developed and tested for several years in Idaho and Arizona. It has also been tested in several areas of the Great Plains during 1969. Testing will be expanded throughout the Plains and the West in 1970. Modifications that are underway include the addition of rainfall probability and the optimization of limited irrigation. A detailed description of this model can be found in several recent papers (Franzoy, 1969; Jensen, 1969; Jensen, et. al., 1969, 1970). A portion of this program has also been included in a related model which will be discussed at a special session on simulation in Plant Science at a conference on Continuous System Simulation Languages, June 10-12, 1970 (Modeling Water and Nitrogen Behavior in the Soil-Plant System by M. H. Frere, M. E. Jensen, and J. N. Carter). The U. S. Bureau of Reclamation has modified the USDA model to provide generalized predictions of irrigation needs for common crops in a given climate-soil regime. This will be tested with cooperators in several areas in 1970.

There are many historical-data ET models in use. Many need refinement to include frequency analyses and crop growth-stress relationships. These relationships are also extremely important in an irrigation optimizing model. Similarly, a soil moisture model, which is a basic component of the present irrigation scheduling model, needs refinement. Studies are underway on these problems that will

eventually result in refined, practical and usable irrigation-oriented ET models. Examples of such studies can be found in recent publications by Fitzpatrick and Nix (1969), Nix and Fitzpatrick (1969), Baier (1969), and Baier and Robertson (1968).

TESTING AND IMPLEMENTING MODEL USE

Testing a model against previous experimental data or under practical field conditions is very important. Verification is needed before users will have confidence in the estimates or predictions. Such testing and verifications are also valuable to the model developers because variables assumed to be unimportant may be found to have a large influence, and extreme refinement in some components of the model may be unjustified if refined input data are required. Usually, greater refinement in the model requires greater refinement of the input data.

One of the greatest barriers to the implementation of ET models is that data currently collected by weather stations are not ET-oriented. Some of these deficiencies are:

1. Meteorological stations are often at cities or airports, and the data collected are not representative of irrigated agricultural areas.

2. Relative humidity is reported (sometimes without temperature at the time of measurement) instead of vapor pressure or dew point which is needed. These data are also collected over a variety of surfaces instead of a standard; i.e., the humidity measured at normal shelter height is not the same in a shelter located in an irrigated field as in a shelter located at an adjacent airport or in a fallow area.
3. Windspeed data in an open agricultural area at a standard height and over a standard surface roughness are needed. The present network is nonuniform, and, in general, measurements are made too close to the ground for nonstandard surfaces. As a result, local fetch conditions have a major influence on the reported data.
4. Several new solar radiation sites are needed to adequately represent the Great Plains area. Solar radiation data are easy to obtain. (Net radiation data are desired but usually these can be estimated from solar radiation and other meteorological data.)
5. Unified and periodic calibrations of instruments against the same standards are needed.
6. Principal stations are needed in selected areas, along with ordinary or auxiliary stations, to represent the Great Plains. These should be tied together with a

modern data communications network. However, instrumentation and routine data collection should not begin until the general requirements of the models developed are known.

7. Other ET model implementation barriers are the lack of trained personnel, crude data communications network, and a general lack of appreciation for the tremendous potential improvement in irrigation water management that is possible with the use of models, especially decision-making models of the climate-crop-soil system. In general, the development and use of practical ET models can shorten the time lapse between research and application substantially.

SUMMARY

An irrigation-oriented ET model is a systematic and organized approach to solving irrigation water management problems. Every researcher should have a model of some type or at least a long-range plan to guide a portion of his research program. An irrigation-oriented, decision-making ET model is in limited use in the Great Plains, but it needs refinement. Plant growth-water stress, or basic yield-soil moisture relationships at various stages of growth are urgently needed. The development of practical ET models for providing decision-making data to the farm manager has a tremendous payoff potential to Great Plains Agriculture, as well as providing a valuable tool for researchers.

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